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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Hazards of
Over-Lubrication

Cloud and Pour Points

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

LUBRICATION CONTROL

"To Increase Machinery's Useful Life"

ANY piece of machinery will function most satisfactorily and show a longer period of useful life when it is effectively lubricated. On the other hand, the best of machine design will be of little avail if the quality of lubrication and the means of application are not properly studied. An excess of lubricant improperly applied is no assurance against wear. In fact, in certain mechanisms such as ball or roller bearings, too much lubricant may cause serious overheating; and in an electric motor, damage to the windings.

The operating factors which impose certain duties upon the lubricants, as well as the various lubricated parts of any machine, must also be fully understood by the operators. Simplicity of design and ready access to all parts have been accepted as fundamental requirements by the builders of modern industrial and power plant machinery. Particular attention has been given to the adaptability of completely automatic lubrication doing away with all complications to assure positive distribution of the lubricant to the various parts.

The Texas Company, in realization of the hazards which may result from over-lubrication, has discussed this important phase of the problem of plant operation in the accompanying issue. Particular attention has been given to methods of automatic lubrication in appreciation of the fact that suitable means of lubrication will most effectively prevent waste, dripping, injury to operators and fire hazards.

THE TEXAS COMPANY

Texaco Petroleum Products

LUBRICATION

A Technical Publication Devoted to the Selection and Use of Lubricants

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Hazards of Over-Lubrication

THERE is a factor in connection with industrial plant lubrication which is very often overlooked entirely by the average operator; i.e., the detrimental results which might accrue from over-lubrication.

The use of the term over-lubrication may seem fallacious, in view of the fact that so many are concerned only with the possibility of under-lubrication, and the detriments which might result from same. It is true, of course, that insufficient lubrication may lead to more important consequences than the use of too much lubricant, for the impairment of any lubricating film will be dangerous, in that it may cause failure of bearings, undue wear, and lead to the necessity of expensive repair work.

In connection with over-lubrication, however, we must consider four serious consequences:

Waste
Expense
Danger to Personnel, and
Fire Hazard.

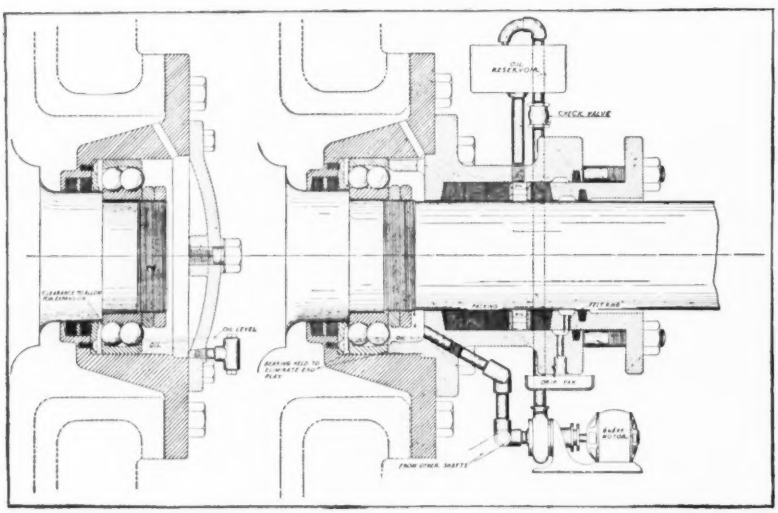
Waste is usually unwarranted. In general, it will lead to expense. This will certainly not be well received by the management if allowed to continue. More important than the actual cost of the amount of lubricant which might be wasted in any plant through over-lubrication is the effect which this may have on personal safety and fire hazard. Unless machinery is surrounded by a proper base, or means to catch and conserve dripped oils, a sloppy condition will result, to involve hazard should an employee slip or fall, and possibly become caught in a train of gears or other moving parts.

It is not unreasonable to state that such conditions may be found in some part of virtually any plant, especially where oil waste can be controlled by individual operators, for all will be careless at some time or other. It is, therefore, essential to educate operators to an appreciation of the fact that sloppy handling of oils or greases may react to their own personal discomfiture quite as readily as to the appearance of their machinery.

Waste can normally be prevented by proper understanding of the various means of lubrication available. This requires study of the types of lubricators employed. Knowledge of the limitations and constructional details of such devices, therefore, will be most beneficial for it will lead to better understanding of the extent to which automatic lubrication can be assured, and the use of better judgment in the selection of lubricants.

It has been definitely proved that waste of lubricants on machine parts which can be effectively housed or protected is related to the means of lubrication. In other words, by judicious selection of a method of application whereby the flow of lubricants can be controlled, waste can be materially reduced. In the handling of fluid oils mechanical force-feed lubricators or circulating systems of unit or gang design are best adapted to modern machine conditions; where greases are involved,

the pressure gun or a system where control of lubricant discharge can be centralized, is most practicable. Throughout, it is a problem of controlled lubrication whereby the amount of lubricant and its direction of flow can be handled in the best interests of the parts to be served.



Courtesy of Minton Vacuum Dryer Corp.

Fig. 1—Showing the oiling system for SKF bearings, as applied to a Minton Vacuum paper drier. Note bearing seal and stuffing box arrangement with method of oil distribution.

The trend in modern machine design is to mechanically lubricate every part and to eliminate the hand oil-can as far as possible. To this end manufacturers are building machines which are becoming more and more nearly automatic in their lubrication. Others who fully realize the detriments of dripped or splashed lubricants, install oil-tight guards or housings, especially around gears and chain drives. Paper mill machinery is noteworthy in this regard, the modern mill having almost completely eliminated the possibility of hazards developing from excessive lubrication.

Any form of lubrication must be positive and the lubricant used must be capable of developing a sufficiently tenacious lubricating film to withstand the operating pressures. This requires selection of quality products, for controlled lubrication necessitates oils and greases which will give maximum protection, especially where delivered in minimum quantities. Knowledge of viscosity or body is essential as an indication of pressure and temperature resisting ability. Carbon residue content is also important where oils for internal combustion engine or high temperature service are involved. When light, medium, heavy, or extra heavy oils are mentioned, it is the viscosity which should be borne in mind; "light" referring to low viscosity, or a range say from 100 to 350 seconds Saybolt at 100 degrees Fahr., "medium" indicating a range of from 350 to 500 seconds. "Heavy" in turn, denotes oils of from approximately 500 to 800 seconds, with "extra heavy" applying to products above the 800 second range.

Excessive friction and power consumption may result from the use of an oil of either too high or too low a viscosity. Too high a viscosity will give a good film but the internal friction in the oil may be excessive; conversely, if the viscosity is too low the film may be broken. The physical characteristic, viscosity, therefore, is of considerable importance in the selection of a lubricant, as it is a measure of the ability of the oil to maintain the proper film under the existing conditions of speed, pressure and temperature. Viscosity must also be considered in conjunction with the pour test, when selecting oils for low temperature service where dependable flow to and from pumping elements, as well as to bearings, gears and cylinders is essential.

METHODS OF LUBRICATION

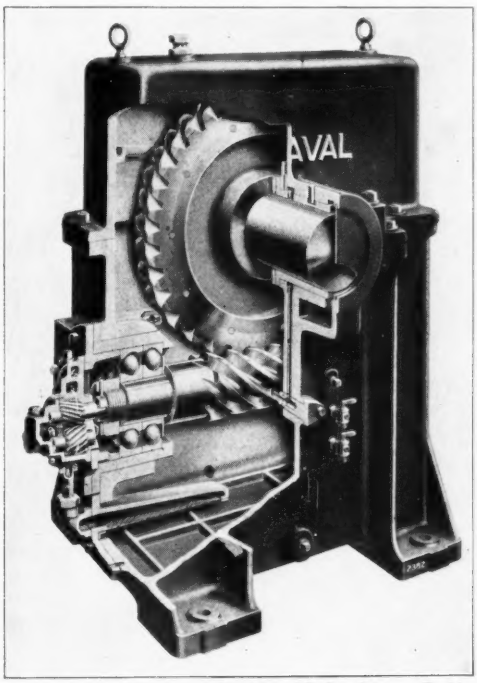
The progressive machine builder equips his units with lubricating systems according to function, size, operating temperatures, bearing pressures and the speed at which the machine must run. No one type is best for every service, although force feed or pressure lubrication have proved to be adaptable to a wide variety of operating and constructional conditions. Other systems involve pressure circulation, splash oiling, gravity feed, ring or chain oilers and pressure grease application.

Where pressure is involved to insure that the machine shall be supplied with the right amount of lubricant from the first move, an attachment or a crank can be located in the lubricating system so that all the pipes and bearings can be primed by manual operation of the lubricator pump. This same objective can also be attained by installing check valves in the delivery pipes as near as possible to the outlet ends. Such valves prevent loss of oil and emptying of the pipes when the machine and oil pump stop operating, insuring retention of oil in the pipes to enable adequate lubrication when operation is resumed.

Mechanical Force Feed Lubricators

Force feed lubrication is widely used as a means of insuring protection of cylinders and pistons of the steam, Diesel or gas engine with the minimum amount of oil. In such service, over-lubrication may be attended by serious after effects, such as carbon accumulation or oil-contaminated exhaust steam, which, by virtue of its oil content, would be detrimental both to process work or boiler feed water where such steam is used as a medium of preheating. The mechanical force feed lubricator can be regarded as involving high pressure lubrication inasmuch as pressures as high as 5,000 pounds per square inch are employed, in comparison with the relatively low pressure systems generally applicable to bearing service.

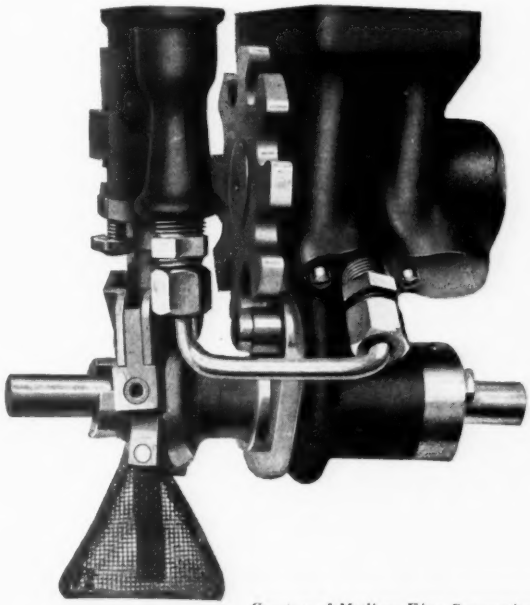
With mechanical pressure or force feed lubrication, each lubricator contains a number of individual adjustable pump plungers receiving their oil supply from the lubricator reservoir. They feed accurately measured quantities of oil to meet the requirements of the parts being lubricated. It is practicable to serve a considerable number of points from any one central system.



Courtesy of DeLaval Steam Turbine Co.

Fig. 2—Cut-away view of a DeLaval worm reduction gear, showing details of the pressure oiling system. The worm threads and teeth of the worm wheel are lubricated by a spray of oil, circulated by a pump through passages in the casing to suitable spray nozzles.

Where mechanical force feed lubricators are used in connection with main bearings and other rotating elements, the clearances are flooded with a continuous and adequate supply of oil which assures the formation and maintenance of a complete lubricant film at all times. A mechanical force feed lubricator being practically always driven by the machine which it serves, only functions when the latter is in operation, and at a proportional speed. The pumping capacity and rate of oil feed is therefore variable. By suitable adjustment of the lubricator it can be very accurately regulated to meet whatever lubricating requirements the moving parts may present. Mechanical force feed lubrication has also been applied to tractor engines and other smaller type internal combustion engines where it is desired to serve both the bearings as well as the cylinders. Oil so fed to the bearings is accumulated in the engine crankcase, filtered and cooled and returned to the lubricator pump for re-circulation, especially where bearing temperatures are not sufficiently high to cause vaporization and marked increase in the viscosity of the oil. It is claimed that this method of tractor engine lubrication reduces the possibility of dilution of crankcase oil to a marked degree.



Courtesy of Madison-Kipp Corporation

Fig. 3—Showing means for reducing a mechanical force feed lubricator to slow speed operation. Note Madison-Kipp pumping unit eccentric, which carries a crank which indexes a rotor in the distributor. This indexing occurs step by step so that for each pressure stroke of the pumping unit a different outlet passage is used.

Pressure Circulation

Continuous circulation of oil through bearings under a definitely controlled pressure affords a very practical and economical way of automatically lubricating such parts with a minimum of labor and attention. As a rule, a considerably greater volume of oil will be handled in a circulating system than where a

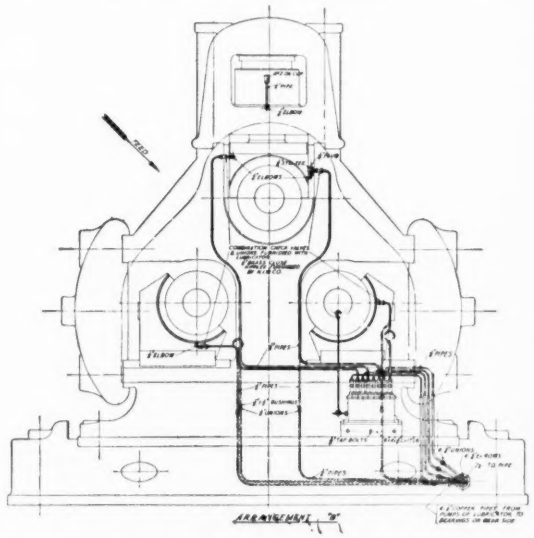
mechanical force feed lubricator is used. A typical circulating system will involve an oil reservoir suitably located with respect to the engine or machine. A pump of the geared or plunger type is used for the transmission of oil either to an overhead or auxiliary tank, or directly to the bearings to be served, with the necessary distributing pipes to each of the latter where an overhead tank is used. Each line should be fitted with a sight feed device and adequate means for individual adjustment of oil flow. Means will also be necessary for drainage or transmission of used oil back to the base reservoir or sump tank. Where oil is fed directly to the bearings from the pump, a relief valve is necessary to enable return of surplus oil to the sump or storage reservoir.

Lubrication by pressure circulation is advantageous in that it provides for sufficient settling of the oil to insure precipitation of the greater part of any foreign matter that may have been picked up by the oil in passage through the bearings. Furthermore, since the latter are practically flood lubricated, they will be cooled as well as washed free from accumulations of foreign matter unless this latter is of a gummy nature resulting from the use of improperly refined oils.

By adequate pressure control it is also practicable to maintain a sufficient pressure on the oil film to resist such operating or reaction pressures as may be developed in certain types of bearings. It is also practicable to equip the pressure gauges of the lubricating system with both high and low pressure alarms to call the engineer's attention to pressures which may be beyond permissible limits.

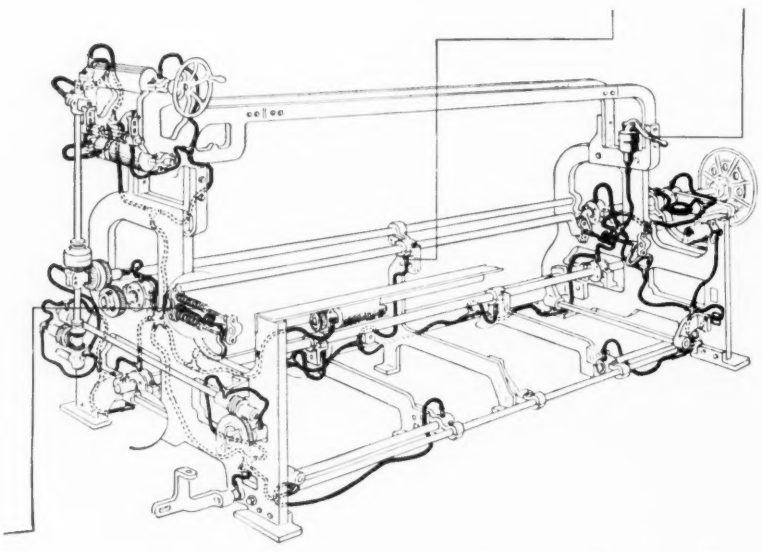
Direct pressure circulation is admirable for lubricating bearings where proper means is installed to completely control the path the oil follows, otherwise leakage may result in considerable waste and hazard. As applied to an internal combustion engine, a resume of a direct pressure system would show a circulating oil pump driven off the engine to deliver the oil under pressure to the main bearings and through ducts to the crank pins, crosshead guides, piston pins, tail rod supports and secondary bearings, according to the type of engine. After passing through the bearings the oil drops back into the crankcase from which it is pumped to a filter or other purifying device from which the oil is again recirculated through the system.

Water cooling coils are sometimes employed to take away the heat acquired by the oil during circulation through any such system. By careful study of inlet and outlet temperatures of oil and water, and use of coils of adequate capacity, very accurate control of fresh oil temperatures can be maintained.



Courtesy of Honolulu Iron Works Company

Fig. 5—Elevation of a set of sugar mill bearings, equipped for force feed lubrication. Note points of application of oil to the bearings.

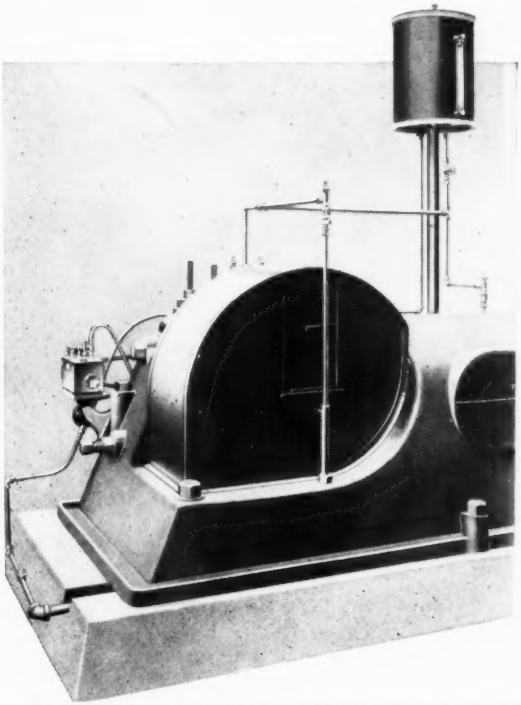


Courtesy of Crompton and Knowles Loom Works

Fig. 4—Line sketch of a loom showing piping elements with location of points of application pertinent to a system of centralized pressure oiling.

Splash Lubrication

Splash lubrication is adaptable to engines or compressors where the circulating oil for the bearings may also often furnish lubrication for cylinders. In this type of system the cylinders depend primarily for their lubrication upon the oil thrown or splashed up from the crankcase. During each stroke an oil film is formed on the lower part of the piston and cylinder walls, which is distributed on each successive upward stroke by the piston rings. The oil drains continually by gravity to the reservoir within the crankcase. Positive lubrication results in such engines because of the generous amount of oil thrown from the moving parts after it passes through the bearings.



Courtesy of DeLaVergne Division, Baldwin-Southwark Corporation

Fig. 6—Showing an oil filter, pump and the distribution piping for a high speed compressor. Note in particular the manner of installation of the lubricator and the sight feed control elements.

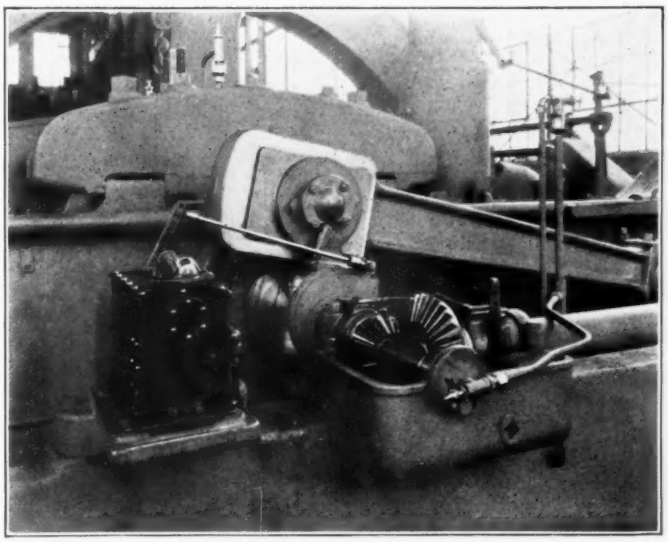
In the interest of proper and continuous distribution of oil, the sump or base of the crankcase must be kept filled to the proper level, which can be automatically maintained by installation of a suitable gauge glass and overflow. This will enable the bottom ends of the connecting rods to dip and either splash or otherwise distribute oil (through suitable ducts) to all interior parts.

Here again, even though flood lubrication prevails, over-lubrication may prove detrimental, especially on internal combustion engines or compressors. Abnormal carbon deposits might readily develop, particularly around piston rings, if the oil level in the case is kept too high and abnormal splash prevails. The location of the overflow should therefore be given careful consideration. The objections to splash with the accompanying possibility of carbon accumulations may be overcome to a certain degree by using a system of oil throw. Here provision is made for oil as it is circulated through the crank bearings to escape and be subsequently thrown to the cylinder walls in sufficient quantities to insure adequate lubrication.

In gas engine service protection of the oil in the crankcase can be insured, and carbonization of oil around the piston rings can be prevented by locating a drain-off connection at the base or inboard end of each cylinder. Any excess oil on the cylinder walls between the bottom follower ring and the scraper ring is accumulated between these two on the down stroke and directed to the drain-off. Experience has indicated that a considerable amount of water developed during the process of combustion can thereby be prevented from entering the crankcase.

Ring, Chain and Collar Oilers

Devices of this nature are adaptable to unit bearing lubrication. A continual delivery of oil is assured to the contact surfaces by means of a ring or chain suspended from the shaft, or a collar fixed thereto, which rotates with the

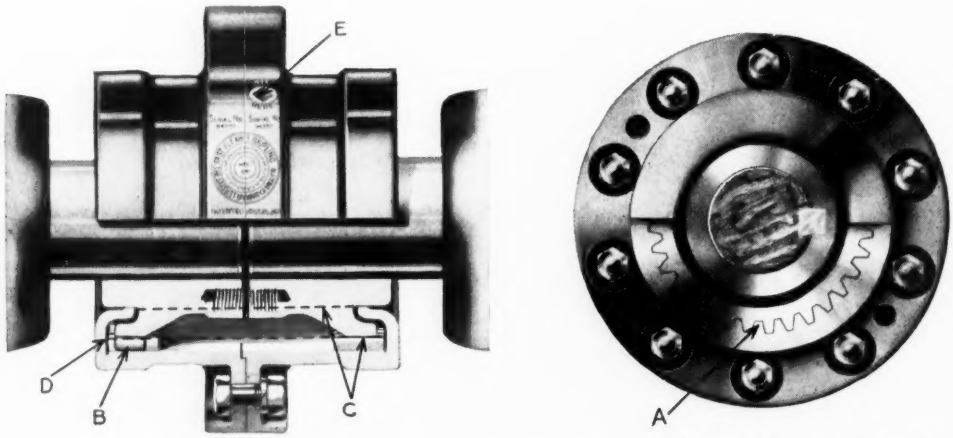


Courtesy of The Cooper-Bessemer Corp.

Fig. 7—Showing an eccentric connection on the drag-crankshaft of a gas engine, which operates a force-feed lubricator for oiling the power and compressor cylinders, and drives a plunger pump for lubricating all bearings.

shaft, the lower part dipping in an oil bath which is carried in a suitable reservoir in the base of the bearing shell. Normally this will circulate oil under practically no pressure.

The reservoir must be of adequate capacity to give the oil ample opportunity to rest, thereby making possible not only the settling out of sediment and other foreign matter, but also cooling to the desired extent.



Courtesy of The Bartlett Hayward Co.

Fig. 8—Cutaway view of the Fast Self-Aligning Coupling; A indicates oil film between gear teeth maintained by centrifugal pressure. B indicates location of load carrying surfaces wherein oil carries the load, C indicates oil levels when the coupling is idle and in operation, D indicates clearance to allow for free lateral float of each shaft.

As a rule, the only way in which the oil in such a system is kept at the proper temperature is by radiation of heat from the exterior surfaces of the reservoir or lower part of the bearing. Oil which is carried to the top of any such bearing must be returned to the reservoir as rapidly as it is delivered by the distributing ring, chain or collar, in order to avoid accumulation in the upper part of the housing and possible occurrence of leakage from the ends of the bearing. The same condition may arise if the oil is carried too high in the well or base of the reservoir. This will cause a splashing and churning of the oil. Otherwise, providing the bearing is properly designed, comparatively no leakage will develop.

METHODS OF PRESSURE GREASE LUBRICATION

Pressure grease lubrication was first developed around the pressure grease cup. On accessible parts it early proved its adaptability. It has however, always been of limited capacity; furthermore it requires periodic attention. The study of means for centralized pressure grease lubrication, therefore, became a logical consequence, along with the design of somewhat similar systems for the application of more fluid lubricants. Today, as a result, lubrication by means of centralized pressure can involve grease or oil according to the design of the lubricating system. The features of any such means of lubrication include positive delivery of lubricant under adequate pressure to insure maintenance of a sufficient film between the bearing surfaces, the exclusion of non-lubricating foreign matter, but little labor to operate, decided economy of lubricants due to reduction in waste and a minimum of hazard in handling or filling.

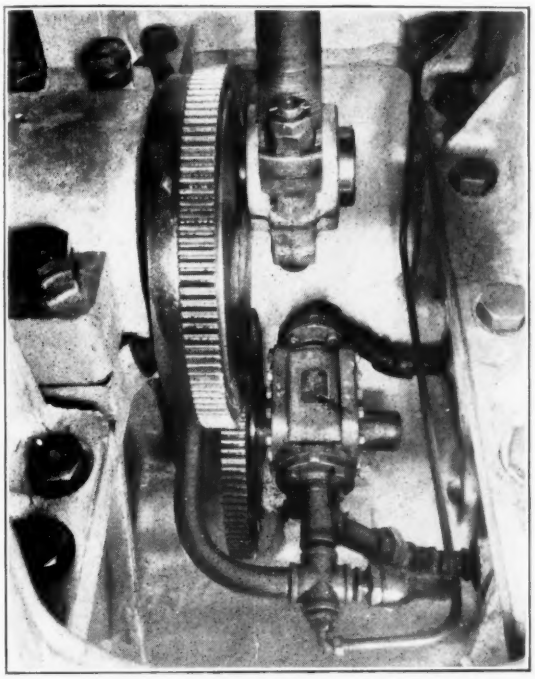
Distribution of comparatively heavy lubricants by means of a central control has been a most interesting development in the study of automatic lubrication. There are a number of ways by which the lubricant can be controlled and impelled to the various points of delivery; all, however, require power.

In systems involving positive piston displacement types of metering valves at each point to be lubricated, hydraulic power has been found to be especially adaptable, as a means of valve control. In such a system either one or two lubricant supply lines can be connected to each valve according to the nature of the service. For heavy duty machinery, dual lines may be employed; one serving to load the respective valves periodically with the right amount of lubricant, the other functioning as the medium for discharging the latter to the bearings.

Other systems involve electric power or compressed air. Certain of these are designed to eliminate the necessity for springs, check valves or restricted port openings. By virtue of the resultant constant pressure which is exerted upon the lubricant, the development of air pockets which might interrupt positive flow, is eliminated.

The pressure gun which followed the com-

pression grease cup in the development of automatic grease lubricating equipment, also lent itself to the operation of certain types of centralized pressure greasing systems. As adapted today it can either be designed for direct connection, thereby becoming an integral part of



Courtesy of Busch-Sulzer Bros. Diesel Engine Company

Fig. 9—A lubricating oil pump located in the crankcase of a four-cycle Busch-Sulzer Diesel engine. This is a positive pressure, gear driven rotary unit, designed to deliver oil to the main, crank and wrist pin bearings under a pressure of from 10 to 12 pounds.

the system, or a portable gun can be used. This device is of decided value as a general piece of plant lubricating equipment, inasmuch as it can be used quite as effectively in connection with individual lubricators as with a centralized system. It can furthermore be used with the spring type of cup with equal dependability.

This combination of the pressure grease gun plus the spring type cup is decidedly advantageous for the lubrication of inaccessible or hazardously located bearings on many types of machinery. As a general rule, by using a spring of particular tension plus a suitable orifice, flow of grease therefrom can be very accurately controlled. An indicator which protrudes through the top of the cover, shows when refilling is necessary.

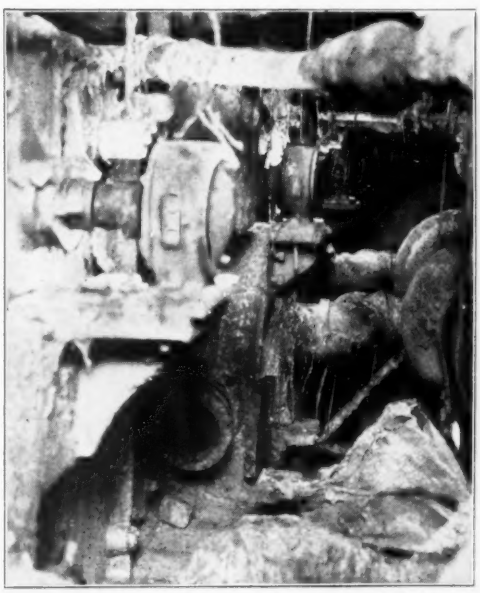
This is a simple and cleanly matter. It merely amounts to attaching the pressure gun to the fitting located in the base of the cup and operating the former until the indicator rises to its full height. There is no necessity for removal of the cover, as with those cups which are more strictly of the hand pressure type. In consequence there is more positive assurance that the grease charge will not become contaminated through possible entry of dust or dirt, or leak or drip to cause waste or hazard.

The necessary pressure to operating the gun may be obtained from compressed air, electric power, or simply hand or foot power, according to the type of gun and the pressure desired. The former develop considerably higher pressures than the latter.

Where a relatively simple hand pressure grease gun is used, the impression may be gained that this should be classified with the hand pressure or screw-down type of cup. Hand pressure as applied to a grease gun does not react directly on the bearing. This pressure must first be converted to mechanical energy by doing work in compressing the spring in the grease cup. From this point on lubrication is automatically maintained by the mechanical action of the spring upon the adjacent plunger which bears upon the grease charge to force it through the bearing.

The Value of Higher Pressures

Where grease lubrication is necessary under higher pressures than can be attained through



Courtesy of Norma-Hoffman Bearings Corp.

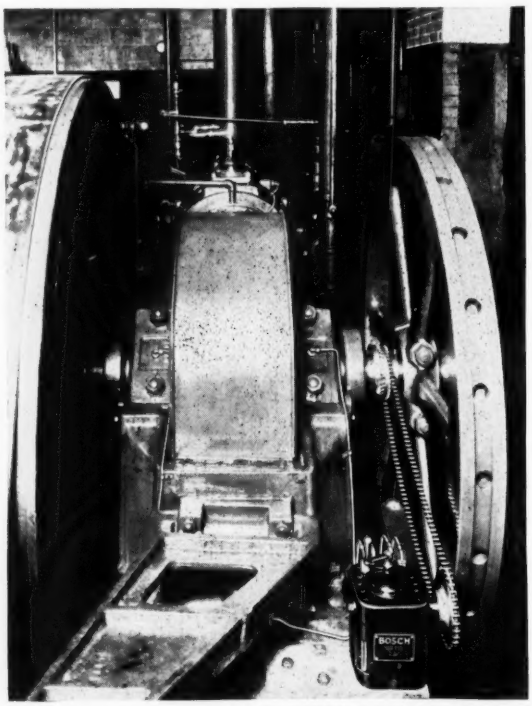
Fig. 10—Showing the drive side of a paper mill cylinder machine. The advantage of using roller bearings under such conditions is obvious.

the average spring type of cup, for the purpose of positive and complete cleaning of bearing clearance spaces and oil grooves prior to relubrication, the power operated gun is of distinct advantage.

To facilitate its usage attention has been

directed to concentration of pressure gun fittings at a central panel or point of control. This has been accomplished with considerable success. Where heavy duty machinery is involved, the extent to which it enables reduction of hazard by concentrating lubrication in a safe location warrants careful study of its adaptability.

Forcing of grease under pressure through the clearance spaces of plain bearings subjected to possible entry of non-lubricating foreign matter serves as a very effective means of forcing out all old grease and any dirt contained therein. Judgment is necessary, however, in determining when this has been completely accomplished and when to shut off the pressure. If properly done, such a method of lubrication is decidedly economical. But if the operator is careless, unobservant, or continues lubrication beyond the necessary extent, he will not only waste grease, but may also cause development of a sloppy condition around the bearings. A slight bulge of fresh grease at a bearing end will usually indicate that complete re-lubrication has been accomplished.

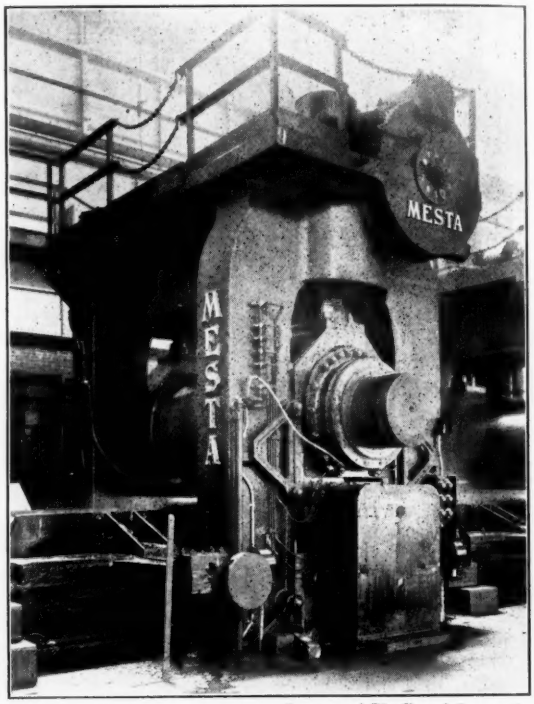


Courtesy of United American Bosch Corp.

Fig. 11—Showing a Bosch positive automatic force feed lubricator attached to a Worthington Feather Valve Air Compressor. Both cylinders and bearings are lubricated by this device.

Lubricator Construction

For the use of the individual machine operator the hand or foot operated pressure gun is generally most suitable. Guns of this type will usually be capable of developing several thousand pounds pressure per square inch. They are practicable either with or without hose connections, according to the type of fitting they are designed for, or the location of the part to be lubricated.



Courtesy of The Farval Corporation

Fig. 12—Showing a type of central greasing unit applied to steel mill operation. In this installation each of the large anti-friction bearings is served with a measured amount of grease at regular intervals of from 10 to 15 minutes. This not only insures adequate lubrication, but is also claimed to prevent entry of dirt, water, or other non-lubricating foreign matter.

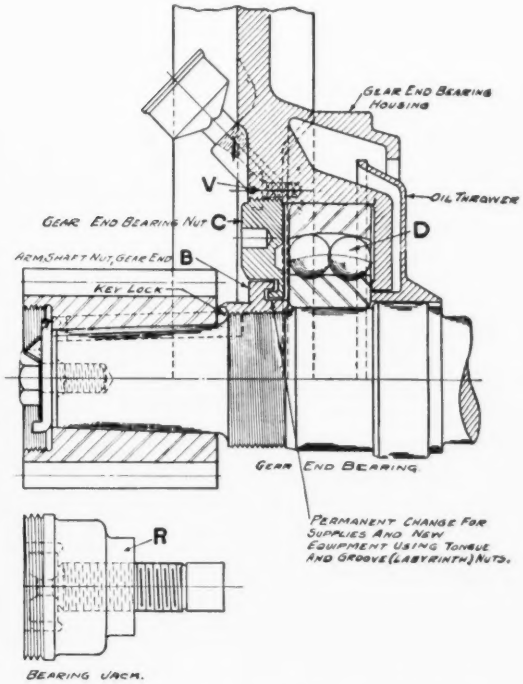
Pressure can be applied either before or after attachment of the gun to the fitting. A frequent method of developing pressure is to force down a suitable plunger by means of a threaded stem which screws into a bushing in the head of the gun. Another type of gun involves pumping action by means of the handle and a suitable pressure retaining device. Where pressure is to be developed before attachment of the gun to the fitting, a suitable check valve must be installed in the tip. In certain guns the act of attachment opens this valve and automatically permits lubricant to be forced in the bearing.

By designing rigid connection guns with check valves the necessity of relieving the pressure is eliminated, before detaching the gun from the fitting; it also enables pressure to be raised before attachment, to overcome the possibility of twisting off the fitting. The direct or swivel jointed connection also does away with the possibility of leaks in the flexible hose.

These factors are especially important where

bearings are to be "started" involving the expulsion of grease which has been allowed to remain too long in the grooves or clearance spaces and consequently become gummed, caked and mixed with dirt.

The mechanical or power lubricator of considerably greater grease capacity, capable of holding 50 pounds of grease or more is best suited to heavy duty machinery where a considerable number of bearings must be served.



Courtesy of The Jeffrey Manufacturing Company

Fig. 13—Showing gear end ball bearing construction on an electric mine locomotive. Note in particular provisions to prevent leakage of lubricant from the bearing.

The smaller capacity guns are chiefly of the hand service type; that is, after pressure is developed grease is discharged by the operation of a pump handle or lever. A ball or check valve at the base of the pump automatically closes at the end of each stroke to retain all pressure that may have been built up. To insure efficient operation this check valve must be inspected at regular intervals to be sure it is kept clean.

In such lubricators pressures of from 1000 pounds upward are readily developed. These are sufficient to handle effectively the usual grades of grease which are applicable to antifriction or plain bearing conditions in the average plant. Power lubricators have also proved to be very suitable for the handling of heavier and more viscous grades of lubricants. They are usually of higher capacity than the hand service type, in certain cases holding as much as 400 pounds of lubricant. In this latter capacity a multi-lead discharge manifold can be installed to enable the lubrication of a number of points simultaneously. Such compressors can be either electrically driven, or designed to take their air from an adjacent compressed air line.

CONCLUSION

By employing means of positive and automatic lubrication wherever practicable, the human factor in the maintenance of effective lubrication is decidedly reduced, not only by virtue of the more positive degree to which oils and greases are applied, but also by elimination of the apprehension which would otherwise exist in an operator's mind were he to be compelled to incur danger periodically in attending to individual lubricating equipment. The hazards of over-lubrication can be eliminated if all concerned with the matter of plant lubrication get together and provide means for applying lubrication which will reduce waste and leakage, and select lubricants which are best suited to this means of application and the operating conditions of their machinery.

Cloud and Pour Points

Their Relation to Low Temperature Lubrication

The behavior of a lubricating oil when subjected to low temperature conditions has led to considerable study of methods of test, to determine accurately the point at which congealment begins and fluidity becomes retarded. In the interest of effective lubrication at low temperatures, this knowledge becomes of considerable value in initial selection of oils which will possess adequate fluidity to enable ready handling in lubricating devices, and maintain protective lubrication of the parts to be served.

The results of these studies with the methods of procedure have been presented by the American Society for Testing Materials under the caption of cloud and pour points.* According to their definition,—

> "(a) The cloud point of a petroleum oil is the temperature at which paraffin wax or other solid substances begin to crystallize out

* A.S.T.M. Method of Test for Cloud and Pour Point, D-97-30, and Tentative Revision, 1933.

or separate from solution when the oil is chilled under definite prescribed conditions.

"(b) The pour point of a petroleum oil is the lowest temperature at which the oil will pour or flow when it is chilled without disturbance under definite prescribed conditions."

Due to the confusion which has prevailed in regard to methods of determining these temperatures, and ignorance in regard to the factors which may have influence upon accurate determination, including preparation of the sample for test, the A.S.T.M. methods of procedure are quoted·

"Procedure for Cloud Point

"The oil to be tested shall be brought to a temperature at least 25 degrees Fahr., above the approximate cloud point. Moisture, if present, shall be removed by any suitable method, as by filtration through dry filter paper until the oil is perfectly clear, but such filtration shall be made at a temperature at least 25 degrees Fahr., above the approximate cloud point.

"The clear oil shall be poured into the test jar, a, to a height of not less than 2 nor more than 2¼ in. The test jar may be marked to indicate the proper level.

"The test jar shall be tightly closed by the cork, c, carrying the test thermometer, b, in a vertical position in the center of the jar with the thermometer bulb resting on the bottom of the jar.

"The disk, e, shall be placed in the bottom of the jacket, d, and the test jar with the ring gasket, f, 1 in. above the bottom shall be inserted into the jacket. The disk, jacket and inside of jacket shall be clean and dry.

"The temperature of the cooling bath, g, shall be maintained at not lower than 30 degrees Fahr. The jacket, containing the test jar, shall be supported firmly in a vertical position in the cooling bath so that not more than 1 in. of the jacket projects out of the cooling medium.

"At each test thermometer reading which is a multiple of 2 degrees Fahr., the test jar shall be removed from the jacket, quickly but without disturbing the oil, inspected for cloud, and replaced in the jacket. This complete operation shall require not more than three seconds. If the oil does not show a cloud when it has been cooled to 50 degrees Fahr., the test jar shall be placed in a second bath maintained at a temperature not lower than 0 degrees Fahr. If the oil does not show a cloud when it has been cooled to 20 degrees Fahr., the test jar shall be placed in a third bath maintained at a temperature not lower than–30 degrees Fahr.

"When such inspection first reveals a distinct cloudiness or haze in the oil at the bottom of the test jar, the reading of the test thermometer, corrected for error if necessary, shall be recorded as the cloud point.

"Procedure for Pour Point

"The oil shall be poured into the test jar, a, to a height of not less than 2 nor more than 2¼ in. The jar may be marked to indicate the proper level. When necessary, the oil shall be heated in a water bath just sufficiently for pouring into the test jar.

"The test jar shall be tightly closed by the cork, c, carrying the test thermometer, b, in a vertical position in the center of the jar with the thermometer bulb immersed so that the beginning of the capillary shall be ⅛ in. below the surface of the oil.

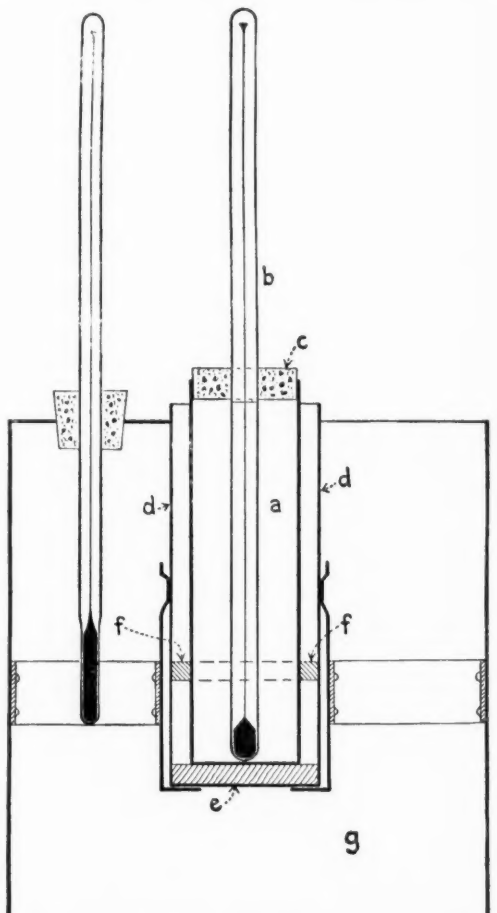


Fig. 14—Showing A.S.T.M. apparatus for determination of cloud and pour points (as assembled for cloud point test). A indicates test jar, B thermometer, C cork in top of A, D a glass or metal watertight jacket, E a cork or felt disk of the same diameter as inside of jacket, F a ring gasket made to fit snugly around outside of test jar and loosely inside jacket, and G is the cooling bath.

"Heat without stirring to a temperature of 115 degrees Fahr., in a bath maintained at not higher than 118 degrees Fahr. The oil shall then be cooled to 90 degrees Fahr., in air or in

a water bath approximately 77 degrees Fahr., in temperature. Oils on which a very low pour point is expected shall be heated as above with the high cloud- and pour-test thermometer in position, cooled to 60 degrees Fahr., and the low cloud- and pour-test thermometer placed in position and the assembly placed in the jacket. Oils on which a pour point of above 90 degrees Fahr., is expected shall be heated to 115 degrees Fahr., or to a temperature 15 degrees Fahr., above the expected pour point, with the high cloud- and pour-test thermometer in position, and the test jar immediately introduced into the jacket.

"The disk, e, shall be placed in the bottom of the jacket, d, and the test jar, with the ring gasket, f, 1 in. above the bottom, shall be inserted into the jacket. The disk, gasket and inside of jacket shall be clean and dry.

"After the oil has cooled enough to allow the formation of paraffin wax crystals, great care shall be taken not to disturb the mass of the oil nor to permit the thermometer to shift in the oil. Any disturbance of the spongy network of wax crystals will lead to low and fictitious results.

"The temperature of the cooling bath, g, shall be maintained at not lower than 30 degrees Fahr. The jacket, containing the test jar, shall be supported firmly in a vertical position in the cooling bath so that not more than 1 in. of the jacket projects out of the cooling medium.

"Beginning at a temperature 20 degrees Fahr., before the expected pour point, at each test thermometer reading which is a multiple of 5 degrees Fahr., the test jar shall be removed from the jacket carefully and shall be tilted just enough to ascertain whether there is a movement of the oil in the test jar. The complete operation of removal and replacement shall require not more than 3 seconds. If the oil has not ceased to flow when its temperature has reached 50 degrees Fahr., the test jar shall be placed in the jacket in a second bath maintained at a temperature not lower than 0 degrees Fahr. If the oil has not ceased to flow when its temperature has reached 20 degrees Fahr., the test jar shall be placed in the jacket in a third bath maintained at a temperature not lower than —30 degrees Fahr. For determinations of very low pour points, additional baths should be maintained with successively lower temperature differentials of about 30 degrees Fahr. In each case the test jar shall be transferred when the temperature of the oil reaches a point 50 degrees Fahr., above the temperature of the new bath. At no time shall the cold test jar be placed directly in the cooling medium. As soon as the oil in the test jar does not flow when the jar is tilted, the test jar shall be held in a horizontal position for exactly 5 seconds, as noted by a stop watch or other accurate timing device and observed carefully. If the oil shows any movement under these conditions the test jar shall be immediately replaced in the jacket, and a test for flow repeated at the next temperature 5 degrees Fahr., lower.

"The test shall be continued in this manner until a point is reached at which the oil in the test jar shows no movement when the test jar is held in a horizontal position for exactly five seconds. Certain lubricating oils tend to move as a whole and should be very closely observed. The reading of the test thermometer at this temperature, corrected for error if necessary, shall be recorded. The pour point shall be taken as the temperature 5 degrees Fahr., above this solid point."

Physical Effect of Temperature

The effect of cold upon petroleum lubricating oils is not the same as upon simple fluids, such as water, alcohol, glycerine, benzine, etc. The latter have fixed and accurately ascertainable freezing points at which a complete change from the liquid to the solid state takes place, but lubricating oils, which are mixtures of hydrocarbons of various melting points, or freezing points, behave like solutions, and frequently deposit some portion of their constituents before the whole mixture solidifies.

Interesting phenomena which can only be explained by change in the inner or molecular structures are observed in the pour test of many lubricating oils. In realization of this fact, as far back as 1924 authorities of the American Society for Testing Materials carried on intensive studies to develop a method of test procedure which would give check results. J. B. Rather and H. M. Anderson* at that time discussed the proposal to secure uniformity in results by pre-heating the sample to some arbitrarily selected temperature. They regarded this as objectionable because they found that the pour test obtained on preheated samples very frequently depends upon the degree of pre-heating. Furthermore, some oils after pre-heating give results which bear no relation whatsoever to the condition the oil will ultimately attain when stored at ordinary atmospheric temperatures. The purpose of their work was, therefore, to secure uniformity in test regardless of any previous heat treatment or storage condition, and at the same time to develop a method of test which would give results directly related to the actual condition of the oil in storage.

In this work, eight oils were selected, most

* Procedure of the A.S.T.M., Volume 24, 1924, Part I, Page 553, Proposed Modification of the A.S.T.M. Pour Test applicable to those oils which give erratic results by the present method.

of them being products which gave abnormal results by varying heat treatments prior to test. In their preliminary experiments the investigators found that in many cases repetition of the A.S.T.M. procedure on the same sample one or more times caused the oil to return to its final equilibrium with regard to pour point, regardless of previous heat treatment, when the equilibrium was taken to be the condition the oil attained in laboratory storage. They also found, however, that heat treatment of certain oils produced a semi-permanent elevation of pour point which was not rectified by this procedure, and that heat treatment of certain others produced a semi-permanent lowering of the pour point which also was not rectified by the method of test.

As a result of this work the investigators reached the following conclusions:

"1. If an oil is heated to any specified temperature prior to testing, or immediately prior to receipt by the testing laboratory, the pour point will depend on the temperature to which the oil has been heated.

"2. In all cases the 'high point,' that is, the preheating temperature at which the maximum possible pour point is attainable, is at about 115 degrees Fahr., and the pour thus obtained more truly represents the ultimate condition the oil will reach in storage than any other.

"3. In order to secure concordant results regardless of any previous heat treatment to which the oil has been subjected prior to receipt by the testing laboratory, it is only necessary to carry out the simple procedure outlined above. No sample, the heat treatment of which has occurred 24 hours previous to testing, requires repetition of the procedure to yield concordant results."

On the basis of this work and more recent developments in studying the behavior of oils containing pour point depressants, the present methods of test, as outlined heretofore, have been formulated. Resultant data developed by Sub-Committee 16 of Committee D-2 of the A.S.T.M. has indicated that by use of a slower rate of cooling it is practicable to ascertain pour tests for oil containing pour point depressants, which will be in conformity with actual performance. The revised method of test can also be applied to other types of oils without affecting the results obtained.

Another factor which has an effect on the test is stirring the oil while cooling to determine the pour test. This is contrary to good practice, for where an oil is stirred, it solidifies at a lower temperature than when held stationary. This may be explained on the assumption that the movement of the oil destroys the formation of a fine network of microscopic particles of paraffinic bodies which are separating out.

This segration gives the oil a certain support and thereby facilitates solidification. In an analogous way this explanation may apply to the influence of pre-heating; the waxy particles being probably transformed by warming into a very strongly dispersed state, from which it is possible to form a finer and thicker network than in the oil which has not been heated.

Conclusion

In conclusion, it is of interest to quote the opinion of the A.S.T.M. in regard to significance of results of cloud and pour tests.*

"The cloud point is of value when the oil is to be used in wickfeed service, or when a haze or cloud in the oil above a given temperature would be objectionable for any reason. However, the test may give misleading results if the oil is not dry, due to the separation of water, and the test should always be interpreted with this fact in mind. In general, the cloud point is of more limited value and narrower range of application than the pour point.

"The pour point gives an indication of the temperature below which it may not be possible to pour or remove an oil from its container, or below which it might be dangerous to use the oil in gravity lubricating systems, where the head tending to produce flow is small. However, it should be borne in mind that the size and shape of the container, the head or force exerted upon the oil, and the nature of its physical structure when solidified, all have an effect upon its tendency to flow. Accordingly, it is self-evident that no single test can be devised which can be taken as a positive and direct measure of the performance of an oil under all conditions of service, and the pour test should be regarded as giving only an indication of what may be expected.

"Consequently, cloud and pour points should be interpreted in the light of actual performance under the particular conditions of use."

* The Significance of Tests of Petroleum Products, Report of Committee D-2 on Petroleum Products and Lubricants, 1929, P. 7, also A.S.T.M. Proceedings, 1928, Volume 28, Part I, Page 485.

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